Sleep Patterns and Affect Dynamics Among College Students during COVID-19 Pandemic: An Intensive Longitudinal Study

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Abstract

Background: Sleep disturbance is a transdiagnostic risk factor so prevalent among young adults it is considered a public health epidemic, exacerbated by the COVID-19 pandemic. Sleep may contribute to mental health via affect dynamics. Prior literature on contribution of sleep to affect is largely based on correlational studies or experiments that do not generalize to the daily lives of young adults. Furthermore, the literature examining the associations between sleep variability and affect dynamics remains scant.

Objective: In an ecologically valid context, using an intensive longitudinal design, we aimed to assess the daily and long-term associations between sleep patterns and affect dynamics among young adults during the COVID-19 pandemic.

Methods: College student participants (N=20, 65% female) wore an Oura ring continuously for 3-months to measure sleep patterns, such as average and variability in total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), and sleep onset latency (SOL), resulting in 1173 unique observations. We administered a daily ecological momentary assessment (EMA) using a mobile health app to evaluate positive (PA) and negative affect (NA), and COVID-worry once per day.

Results: Participants with higher SOL and TST on the prior day had lower PA the next day. Further, higher average TST across the 3-month period predicted lower average PA. TST variability predicted higher affect variability across all affect domains.

Conclusions: Fluctuating sleep patterns are associated with affect dynamics at daily and long-term scales. Low PA and affect variability may be potential pathways through which sleep has implications for mental health.

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Author contribution:

Zahra Mousavi: Study conceptualization and design, conducted data analysis, and drafted the manuscript.
Jocelyn Lai: Assisted with study conceptualization and design, edited the manuscript, contributed to the analytic plan.
Katherine Simon: Contributed to study conceptualization, to contextualizing the contribution of the study within the literature, and to manuscript editing.
Alexander P. Rivera: Assisted with data preparation and manuscript writing.
Asal Yunusova: Assisted with data preparation and manuscript writing.
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Jessica L. Borelli: Assisted with study conceptualization and design, edited the manuscript, contributed to the analytic plan.
All edited and approved the manuscript.

Abstract

Background: Sleep disturbance is a transdiagnostic risk factor so prevalent among young adults it is considered a public health epidemic, exacerbated by the COVID-19 pandemic. Sleep may contribute to mental health via affect dynamics. Prior literature on contribution of sleep to affect is largely based on correlational studies or experiments that do not generalize to the daily lives of young adults. Furthermore, the literature examining the associations between sleep variability and affect dynamics remains scant.

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Results: Participants with higher SOL, *b*= -1.09, *SE*=.36, *p*=.006, and TST, *b*= -.15, *SE*= .05, *p*=.008 on the prior day had lower PA the next day. Further, higher average TST across the 3-month period predicted lower average PA, *b*= -.36, *SE*= .12, *p*=.009. TST variability predicted higher affect variability across all affect domains. Specifically, higher variability in TST was associated higher PA variability, *b*=.09, *SE*= .03, *p*=.007, higher NA variability, *b*=.12, *SE*= .05, *p*=.03, and higher COVID-worry variability, *b*= .16, *SE*= .07, *p*= .04.

Conclusions: Fluctuating sleep patterns are associated with affect dynamics at daily and long-term scales. Low PA and affect variability may be potential pathways through which sleep has implications for mental health.

Keywords: sleep, objective sleep outcomes, affect variability, affect dynamics

Introduction

Sleep is a robust and transdiagnostic risk factor for various physical and mental health problems including mood disorders [1–3]. Indeed, sleep disorders such as insomnia and circadian misalignment contribute to the development or recurrence of mood disorders, particularly depression and anxiety [4]. Variability in sleep duration, as measured by day to day changes in nightly sleep, is as important a predictor for psychological well-being as the average total amount of sleep [5]. Sleep problems such as chronic sleep restriction and irregular sleep patterns are common among college students [6]. For emerging adults who are already at greater risk for psychopathology [7,8], the COVID-19 pandemic has disrupted daily routines [9,10], potentially exacerbating variable sleep patterns, contributing to further insufficient sleep and greater variability in sleep duration. Given the prevalence of sleep disturbances as well as impact of the pandemic on young adults, it may be important to examine the associations between sleep and affect in young adults during the COVID-19 pandemic.

Insufficient sleep and sleep variability may contribute to physical and mental health via affect dynamics. Positive (PA) and negative affect (NA), broadband indices of emotion, are well-established predictors of well-being [11]. Blunted positive affect and increased negative affect are risk factors for and significant predictors of the development and recurrence of mental disorders - such as depression. COVID-worry or concern of COVID-19 infection is another relevant affect construct during the pandemic [12,13]. COVID-worry has been discussed at length by psychologists during the COVID-19 pandemic (e.g.,[12-14]) and is a distinct psychological factor, uniquely contributing to general anxiety and persistent pessimism [12]. Affect, however, is dynamic - the trajectory of emotional experiences often fluctuates across time [15]. Above and beyond average affect, daily affect dynamics such as affect variability may contribute to explaining individual differences in psychological functioning. Affect variability, a measure of the extent to which individuals experience frequent PA,NA, and COVID-worry fluctuations is known to play a prominent role in psychopathology, such as mood disturbances [16,17].

Prior literature has mainly focused on the negative consequences of sleep deprivation on average PA and NA, finding that sleep duration significantly predicts dampened PA and elevated NA [18-22]. Experimental studies also confirm the similar effects of sleep loss on changes in PA and NA [23,24]. Specifically, one night of sleep deprivation or/and sleep restriction (i.e. 4 hours of sleep) compared to idealized sleep (i.e. opportunity of sleeping for 9.5-10 hours of sleep) decreases PA such as vigor and increases NA such as anger [23,24]. Yet, this knowledge is largely based on correlational studies or sleep deprivation experiments that do not generalize to the daily lives of chronically sleep restricted young adults. Additional studies on the relation between affect and sleep problems in young adults in a more ecologically valid context (e.g., daily life) may help to elucidate these associations. Furthermore, to date, the literature examining the associations between daily sleep variability and affect dynamics remains scant. Daily sleep variability contributes to psychological well-being [5,25] but more studies using newer methods to examine objective sleep are needed. Intensive longitudinal designs conducted over longer periods of time assessing both subjective and objective sleep outcomes are poised to accomplish these goals. Considering the important contribution of poor sleep to mood disorders, particularly depression and anxiety [4,19], it is important to examine the nuanced characterizations of the consequences of daily sleep disturbances on affect dynamics. Examining the association between daily sleep and affect will allow for a better understanding of the development of comorbid sleep and mood disorders and designing prevention programs for

at-risk individuals.

The aim of the current study was therefore to assess 1) the daily associations between sleep and affect, and 2) the long-term associations between sleep patterns such as average and variability in total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), sleep onset latency (SOL), and affect dynamics such as mean-levels of PA and NA, PA and NA variability, and COVID-worry dynamics among young adults during the COVID-19 pandemic across a 3-month period. Examining these associations at between and within-person levels will allow for improved understanding of the development of comorbid sleep and mood disorders and support the identification of early intervention windows for at-risk individuals. This study was designed to examine sleep among young adults in a 3-month period, however, the period of assessment varied from 1 month to 3 months due to retention. The majority of previous studies have assessed subjective and objective sleep outcomes in a 14-day period (e.g., [5,25]), meaning that the current study examined a longer period of time. Further, multilevel modeling is a powerful analytic approach to analyze intensive longitudinal data with missing values for both between and especially for within-subject research questions.

Method

Participants

College student participants (N = 20, 65% female, M_{age} = 19.80, SD_{age} = 1.0) were assessed daily across a 3-month period during the 2020 COVID-19 pandemic (range: June-November), resulting in 1173 unique observations. Participants were eligible if they met the following criteria: unmarried, English speakers, full-time undergraduate students between the ages of 18-22, and owned a primary Android smartphone compatible with the ecological momentary assessment (EMA) phone-based survey applications and study wearable devices.

Procedure

The present study was part of a larger intensive longitudinal study to examine student mental health [MASKED] that included physiological assessments, sleep tracking, and daily emotional and behavioral reports. The procedures of this study were approved by the Institutional Review Board (#2019-5153) at University of California, Irvine. All individuals provided written informed consent prior to participation. We describe procedures relevant for the purposes of the current investigation. Participants were first instructed on how to wear the non-invasive device (i.e., Oura Ring) that continuously assessed sleep, activity, and physiology throughout the day and during sleep [26]. Participants completed daily surveys on affect using a smartphone application. To maintain high adherence, participants received reminders via text, email, or phone if there were more than 2 days of inactivity.

Measures

Sleep

Using the Oura ring (manufacturer: the Ōura Health Ltd, Specifications: 2 x infrared LED heart rate sensor, 2 x NTC body temperature, 3-axis accelerometer, and Gyroscope), total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), and sleep onset latency (SOL) were calculated through the detection and interpretation of physiological measures, including heart rate, heart rate variability, and pulse wave variability amplitude. Previous studies have compared Oura ring to polysomnography (PSG), the gold standard of sleep measurement, and research grade actigraphy (Philips Respironics, USA). The study by [27] shows that based on epoch-by-epoch (EBE) analysis, Oura ring yields comparable sleep assessment to actigraphy [27], but underestimates total sleep time (TST)

compared to PSG. However, other studies (e.g.,[28]) show that summary variables for sleep onset latency (SOL), total sleep time (TST), and wake after sleep onset (WASO) are not different between Oura ring and PSG. This validation study by [28] is conducted among healthy adolescents and young adults and shows that "the differences for TST and WASO between PSG and Oura are within the ≤ 30 min a-priori-set clinically satisfactory ranges for 87.8% and 85.4% of the sample, respectively." This study also shows that the Oura ring is able to categorize sleep with accuracy of above 81.3% to PSG defined TST ranges (e.g., <6h, 6-7 h, >7h). However, there are some concerns regarding detecting the stage of the sleep (e.g., light sleep, deep sleep, REM sleep) and therefore, the stages were not included in the current study.

Affect and COVID Worry

As part of the ecological momentary assessment (EMA) phone-based surveys, participants reported daily PA and NA using the Positive and Negative Affect Schedule each evening (PANAS [29]. Ten positive (e.g., inspired) and ten negative (e.g., nervous) items were rated, respectively, on a 0-100 scale (0 = "Very Slightly"; 100 = "Extremely"). A total score of PA and NA was calculated using an average across each 10-item subscale (PA *M*=45.27, *SD*=20.22, alpha = .85; NA *M*=21.79, *SD*=12.28, alpha = .91). As a separate item ("How worried were you about contracting COVID today?"), participants reported their COVID worry on a 0-100 scale (*M* = 17.41, *SD* = 19.15)."

Sleep and Affect Variability

To determine the variability of each sleep and affect variable, we created a series of successive differences by calculating the difference between two successive observations within the same subject (e.g., night 2 - night 1, night 3 - night 2, etc). Next, these values were squared. We used the square successive differences (SSDs) to compute a mean square successive difference (MSSD) score. Finally, we calculated the root mean square successive difference (RMSSD) score for each participant. The RMSSD is considered as an index of variability, similar to the intra-individual variance of a series of observations but more sensitive to fluctuations across successive observations [30].

Data Analysis

We first examined variables for normality and heteroscedasticity. To examine the association between sleep (TST, SE, SOL) and affect variables (PA, NA, COVID- worry), we first conducted multilevel models using Restricted Maximum Likelihood (REML). This approach improves estimates of variance components and fixed effects standard error estimates in smaller samples by separating the estimation of the fixed effects from the variance components [31].We predicted PA, NA, and COVID- worry as a function of fixed effects of time, between- and within- sleep variables, while controlling for previous day affect. Next, we examined the association between sleep and affect variables using multiple regression models. Previous studies have found that gender is linked with sleep outcomes [32–34]. Therefore, gender was included as a covariate in these regression models. Finally, we conducted hierarchical linear regressions to examine whether sleep variability variables contribute to affect dynamics above and beyond the sleep average variables.

Results

Descriptive statistics

20 college students (65% females, n_{female}=13) completed the study, providing 1623 (*M* ± *SD*= 43.49 ± 25.51 day/person) nights of usable Oura ring sleep data respectively.

Completion rates for EMA studies were high (83%).
Multimedia Appendix 1: Table 1 provides descriptive statistics and the bivariate correlations between the key variables. The average of participants' total sleep time and total sleep time variability were 6.84 and 1.8 hours, respectively. Participants also experienced an average of 65.04 and 12.01 minutes of WASO and SOL, respectively with SE of 86.52% across the study. Further, on average, participants reported low levels of NA (*M* = 21.79), moderate levels of PA (*M* = 45.27), and low levels of COVID-worry (*M* = 17.41) across the study. We assessed the bivariate correlation between COVID-worry mean and PA and NA means (between-person level) and found no significant correlation between these constructs. Specifically, the correlation between COVID-worry mean and PA mean was -.19 (*p*=.43) and the correlation between COVID-worry mean and NA mean was .43 (*p*=.06).

Daily sleep and daily affect

Multilevel models of the relation between sleep and affect revealed that participants with higher SOL, *b*= -1.09, *SE*=.36, *p*=.006, and TST on the prior day, *b*= -.15, *SE*= .05, *p*=.008 had lower PA the next day, while controlling for previous day PA. No within-subject differences were observed in predicting next-day PA. No associations between daily sleep with NA and COVID-worry were found.

Main effects of sleep on average affect

The regression model predicting PA from average TST accounted for 34% of the variance in average PA, *Adj.* R^2= .26, *F*(2, 17)= 4.24, *p*=.028. Specifically, higher TST was associated with lower PA, *b*= -.36, *SE*= .12, *p*=.009. Other sleep variables were not associated with average PA. Sleep was not associated with average NA or COVID-worry (Please see Multimedia Appendix 2: Table 2 for more details).

Main effects of sleep on affect variability

Sleep average and affect variability

SOL and SE predicted COVID-worry variability. The multiple regression model predicting COVID-worry variability from average SOL and gender accounted for 38% of the variance in COVID-worry variability, *Adj.* R^2= .31, *F*(2, 17)= 5.29, *p*=.02, and the model from average SE and gender accounted for 38% of the variance in COVID-worry variability, *Adj.* R^2= .31, *F*(2, 17)= 5.24, *p*=.02. Specifically, higher average SOL predicted higher COVID-worry variability, *b*= 1.87, *SE*= .89, *p*=.05, and higher SE predicted lower COVID-worry variability, *b*= -2.02, *SE*= .97, *p*=.05. Please see Multimedia Appendix 3: Table 3 for more details.

Sleep variability and affect variability

The multiple regression models predicting affect variability from TST variability, while controlling for gender, accounted for 36% of the variance in PA variability, *Adj.* R^2= .29, *F*(2, 17)= 4.82, *p*=.02, 34% of variance in NA variability, *Adj.* R^2= .27, *F*(2, 17)= 4.44, *p*=.028, and 40% of variance in COVID-worry variability, *Adj.* R^2= .33, *F*(2, 17)= 5.70, *p*= .01. Specifically, higher variability in TST was associated higher PA variability, *b*=.09, *SE*= .03, *p*=.007, higher NA variability, *b*=.12, *SE*= .05, *p*=.03, and higher COVID-worry variability, *b*= .16, *SE*= .07, *p*= .04. Please see Multimedia Appendix 3: Table 3 for more details.
The hierarchical regression models showed TST variability predicted PA variability above and beyond average TST, *Adj.* R^2= .26, *F*(3, 16)= 3.20, *p*= .05. However, models predicting NA variability and COVID-worry variability were only marginally significant after adding average TST to the model, *Adj.* R^2= .22, *F*(3, 16)= 2.82, *p*= .07, and *Adj.* R^2= .22, *F*(3, 16)=

2.82, *p*= .07, respectively.

Discussion

Sleep patterns across daily and long-term scales were associated with daily and average affect and affect variability assessed over a 3-month period. These findings resonate with prior work suggesting that poor sleep confers heightened risk for affective disturbances prevalent in mood disorders such as depression [4]. The link between sleep variability and affect variability may provide a window into how such patterns develop over time.

Individuals with longer sleep time the night before experienced lower PA the next day. Similarly, individuals with longer average TST over the study period reported lower PA. Previous studies, however, have suggested a positive association between sleep duration and greater positive affect (e.g.,[25]). During COVID, young adults' lives changed dramatically [35] and it is possible that they were sleeping above the recommended hours; therefore, there may be a curvilinear association between TST and positive affect. Future studies may benefit from examining this curvilinear association in a larger sample. Notably, consistent with prior studies [36], sleep did not predict NA. Low PA may be one potential pathway through which sleep duration has implications for mental health. Low PA is both a significant predictor of the onset of depression, as well as a characteristic of depressive disorders. When PA is directly treated, symptoms of anxiety and depression, as well as other disorders with anhedonic features are known to improve [37]. Thus, improving daily sleep may be particularly important to prevent positive affect decline, potentially interrupting the pathogenesis of illness states such as mood disorders.

TST variability predicted higher affect variability across all affect domains (i.e., PA, NA, COVID-worry), and thus may be a proximal predictor of mood disturbances. Affect variability is prevalent in various mood-related disorders such as depression, bipolar disorder, and anxiety disorders [38]. Our findings have important implications. First, interventions to support sleep stability may indirectly reduce affect variability, and therefore prevent clinically significant mood disturbances. For example, in bipolar disorder, variable sleep and affect during euthymia predict worse long-term outcomes, including episodic relapses [39]. Second, our findings suggest that stabilization of affect may be an early marker or predictor of efficacy of transdiagnostic sleep interventions targeting mood disorders with anhedonic features [39]. Future research may benefit from experimentally investigating the effect of regulating sleep time on affect dynamics in clinical populations.

Our findings also provide specific relevance to the COVID-19 context. Individuals with higher SOL experienced higher COVID-worry variability, and those with higher SE reported lower COVID-worry variability. Specificity of the association between SOL and SE average, and COVID-worry variability (i.e., not NA in general) may suggest the unique association between sleep and arousal-related affect compared to other NA subtypes. Sleep disturbances may contribute to lower capacity to adaptively overcome stress, and therefore be associated with higher stress-related sleep reactivity and cognitive pre-sleep hyperarousal [40]. Future research may benefit from experimentally investigating the association between sleep and specific subtypes of affect.

Limitations

Our findings carry some limitations. First, whether sleep causally predicts affect remains unclear. Daily affect may also predict multiple sleep indices [36]. The bidirectional link between sleep and affect may result in a cyclical pattern of sleep disturbance impacting affect, which in turn may contribute to greater sleep disturbances. Further, the small sample

size of this study was not diverse in age, limiting the generalizability of our findings to other age groups. However, the peak prevalence of affect variability is among young adults (16-24 years old) and gradually declines with age [38]. Considering the small sample size of this study, future studies may benefit from examining the association between sleep patterns and affect dynamics in a larger sample.

Conclusion

Fluctuating sleep patterns are associated with affect dynamics such as average PA and affect variability across all affect domains (i.e., PA, NA, COVID-worry) at daily and long-term scales. Low PA and affect variability may be potential pathways through which sleep has implications for mental health. Interventions targeting sleep stability may indirectly reduce affect variability, and therefore prevent mood disorders. Stabilization of affect may be an early marker or predictor of efficacy of transdiagnostic sleep interventions targeting mood disorders with anhedonic features.

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Supplementary Files

Multimedia Appendixes

Table 1 Means, standard deviations, and correlations between sleep and affect variables.
URL: http://asset.jmir.pub/assets/58720946e58fc8d327029918fd145fe7.docx

Table 2. Adjusted estimates predicting average affect from objective sleep, gender, and age.
URL: http://asset.jmir.pub/assets/ba69316343d9b7795d54c7ef3dcaee97.docx

Table 3 Adjusted estimates predicting affect variability from objective sleep, gender, and age.
URL: http://asset.jmir.pub/assets/185bd346f3d9f8ae0b7907f00f86b3fe.docx

Table 4 Unstandardized coefficient estimates in models predicting daily sleep by daily affect.
URL: http://asset.jmir.pub/assets/2b48567aec07ffbf0bf6f1cfd52777ae.docx